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AUTHOR Aubrecht, Gordon J., II
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ABSTRACT

The twentieth century has witnessed a burst of discovery in physics unparalleled in human history. Despite the fact that general relativity and quantum mechanics are well over half a century old, introductory physics classes in high schools, colleges, and universities essentially ignore them. These two seminal ideas, the phenomena of superconductivity (teens), holography and nuclear fission (1940s) nuclear fusion and semiconductor physics (1950s), maser and laser physics (1950s and 1960s), explication of phase changes (1960s and 1970s), gauge theories and QCD (1970s), and unification of cosmology and particle physics (1980s) are all but ignored. Mere mention of these, as well as nuclear magnetic resonance (NMR) and radiotherapy used in medicine, would help to give students a feeling for the diversity and vitality of physics and its attendant technology. A few examples integrating vital fields of physics into a normal curriculum are given. (Author/JN)

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IS THERE ANY PHYSICS AFTER THE END OF THE NINETEENTH CENTURY?

Gordon J. Aubrecht II*
American Association of Physics Teachers
University of Maryland
College Park, MD 20742

ABSTRACT

The Twentieth Century has witnessed a burst of discovery in physics unparalleled in human history. Despite the fact that general relativity and quantum mechanics are well over half a century old, introductory physics classes in high schools, colleges and universities essentially ignore them. These two seminal ideas, the phenomena of superconductivity (teens), holography and nuclear fission (forties), nuclear fusion and semiconductor physics (fifties), maser and laser physics (fifties and sixties), explication of phase changes (sixties and seventies), gauge theories and QCD (seventies), and unification of cosmology and particle physics (eighties) are all but ignored. Mere mention of these, as well as NMR and radiotherapy used in medicine, would help to give students a feeling for the diversity and vitality of physics and its attendant technology. A few examples integrating vital fields of physics into a normal curriculum will be given.

* On leave from the Ohio State University.

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If one looks at most physics text books at the introductory level, by which I mean those meant for the engineering and biological science sequences, it is almost impossible to find any material reflecting the physics research in the Twentieth Century.

Only special relativity (1905) and the Bohr model (1912) make it into a reasonable number of textbooks. Those textbooks which do treat some Twentieth Century physics topics do so in special chapters; there is no real integration of any of the new material into the standard topic areas.

What has happened in the Twentieth Century in physics? We all are aware of the unparalleled burst of research. I list a few areas of advances below, making no claim of completeness:

GRAVITATION and related areas--special relativity, General Relativity, Hubble expansion, black holes, quasars, neutron stars, quantum black holes, supergravity.

NUCLEAR PHYSICS--quantum theory, discovery of the neutron, nuclear fission, radioactive decay (tunneling), explication of nuclear structure, nuclear fusion and creation of plasmas, NMR, symmetries in nuclei, Mossbauer effect.

PARTICLE PHYSICS--quantum theory, discovery of the muon and pion, symmetres, eightfold way, scattering experiments, four forces, electroweak interaction, QCD, GUTs and prediction of proton decay, superstrings, supergravity.

CONDENSED MATTER--superconductivity, quantum fluids, semiconductors (transistors replacing vacuum tubes), BCS theory, phase transitions, Josephson effect, SQUIDs, chaos, quantum Hall effect.

OPTICS--Planck blockbody radiation spectrum, holography, masers, lasers, nonlinear optics.

ATOMIC PHYSICS--explanation of atomic spectra, quantum mechanics, molecular orbitals, EPR.

Sketchy as this list is, it indicates clearly the excitement and the breadth of modern physics research. We are just not reaching out to involve our own students in this ferment of activity.

Quantum mechanics has had an incredible effect on the concept of the physical universe. The Heisenberg uncertainty principle has often been cited, even if incorrectly, in the popular media. Neils Bohr and the physicists in Copenhagen (and elsewhere in Europe) grappled with the wrench from the classical world to a world governed by quantities which come in unitary bits. The ideas of complementarity and correspondence brought the philosophers to the melding of quantum ideas with those from classical physics.

Without quantum theory, almost none of modern physics would have developed. We may explain alpha-decay by tunneling, and, of course, this idea is important not only for the Josephson effect, but also for such mundane applications as the tunnel diode. Particle physics is now a fully covariant quantum theory. Ideas such as supersymmetry world be inconceivable without the prior development of quantum mechanics and the generalized Pauli principle.

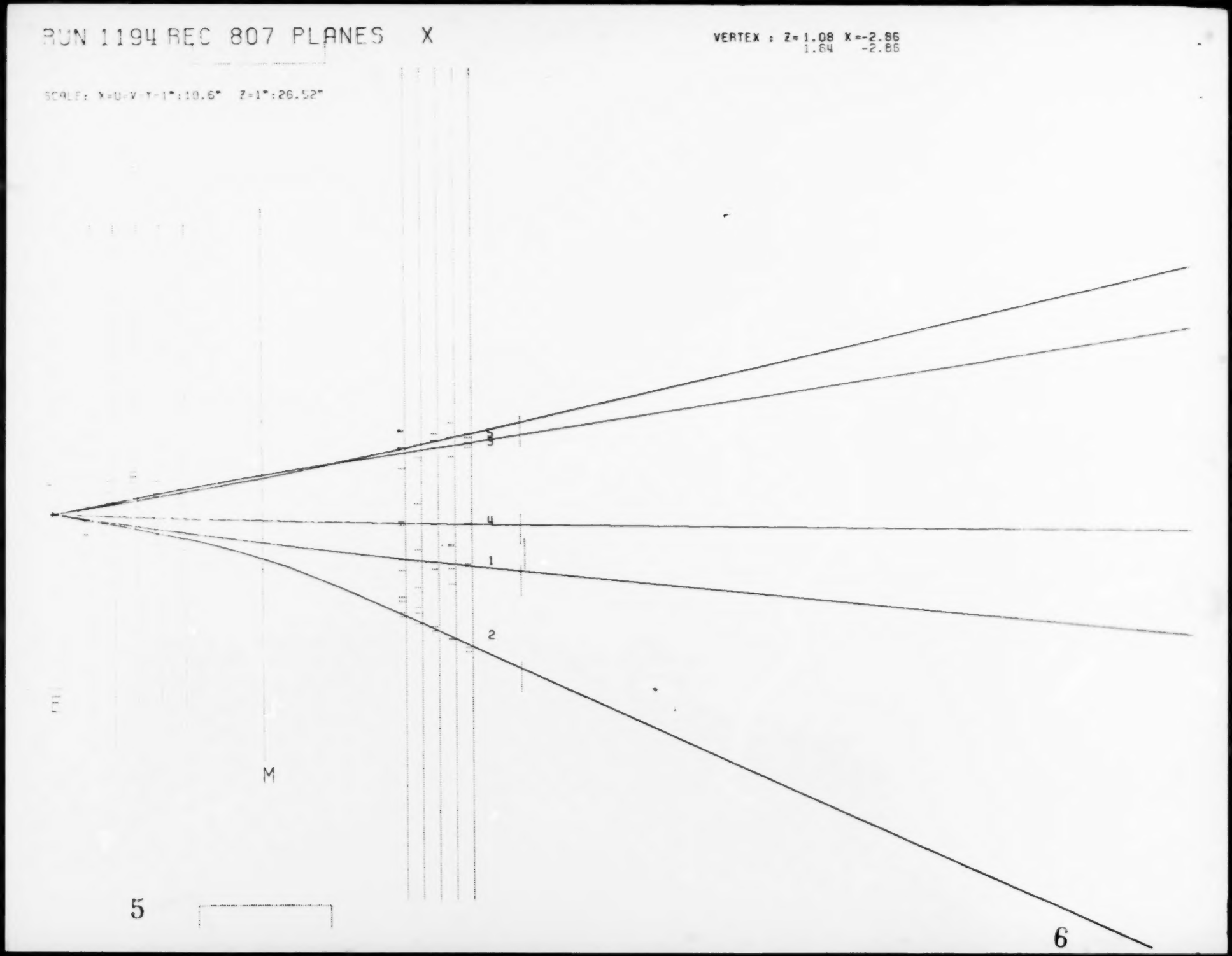
The other seminal idea of the Twentieth Century is that gravity results from the presence of matter distorting the geometry of space. Geodesics are followed by particles, but these are not the geodesics of flat space. Space is curved. To discuss this phenomenon, tensor calculus is essential. Luckily for Einstein, the mathematics had already been developed by Riemann. General relativity took much longer to be accepted than Quantum Mechanics, and suffered unfairly in people's conception because it had a reputation for incomprensibility.

Even when we do introduce a few selected topics in modern physics to our students, we discuss them in isolation. However, as we know, modern physics represents the synthesis of basic physics we attempt to teach our students, such as conservation of energy and conservation of momentum. Thus, many of these simple ideas are amenable to explication and examples through modern physics. When I was a college sophomore, I worked for a high energy physics experimental group scanning bubble chamber films. One of the group's graduate students, Paul Kramer, took the time to demonstrate for me conservation of momentum in pi-minus-proton collisions, graphically. Of course, we had to do this using three stereoscopic views, which was fine since I was a sophomore physics major; we can clearly find examples of momentum conservation which are two-dimensional . The idea may be demonstrated by using material from the Fermilab experiment E-531 (see the accompanying figures). From the three different views, we may reconstruct the entire track in space. Most modern physics experiments do just this as part of the analysis. Such material provides one way to incorporate these results of modern physics experiments into the traditional curriculum.

The ideas of NMR and EPR could be discussed as well--we do discuss the Larmor frequency in talking of the tracks of particles in magnetic fields; why not just extend the discussion slightly? The aurora borealis can also be understood in terms of an electron plasma spiraling around the lines of earth's magnetic field.

Optics is often discussed in elementary physics courses, but seldom is the topic of lasers considered, and seldom is coherence or stimulated emission discussed. Some of these topics could be "stimulating" additions to the usual optics topics.

Similarly, there is no reason that one cannot give examples for energy conservation in fission or fusion reactions using the curve of the average binding energy per nucleon versus mass number. One may also refer to general relativity with a reference to the Pound-Rebka experiment.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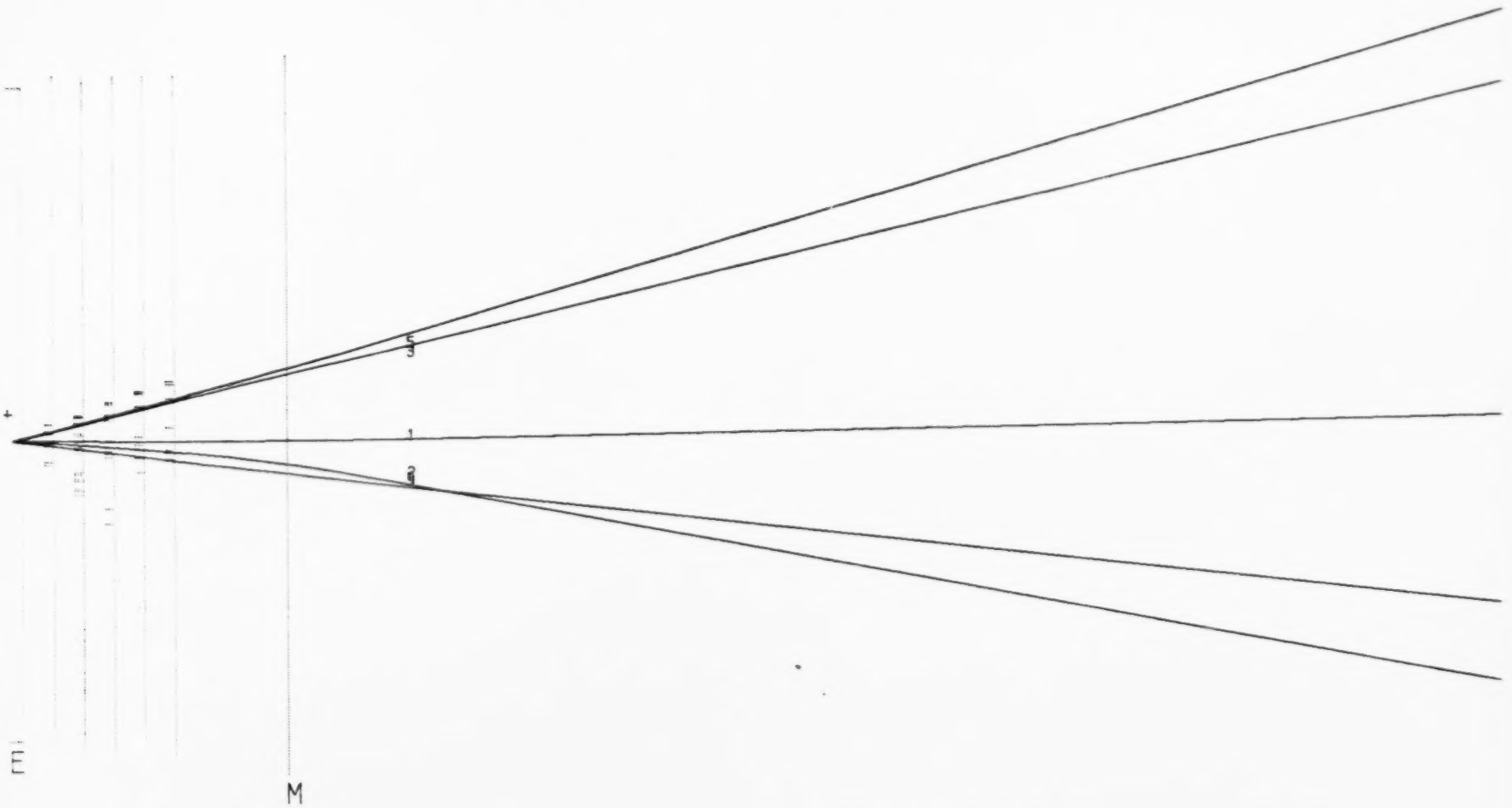

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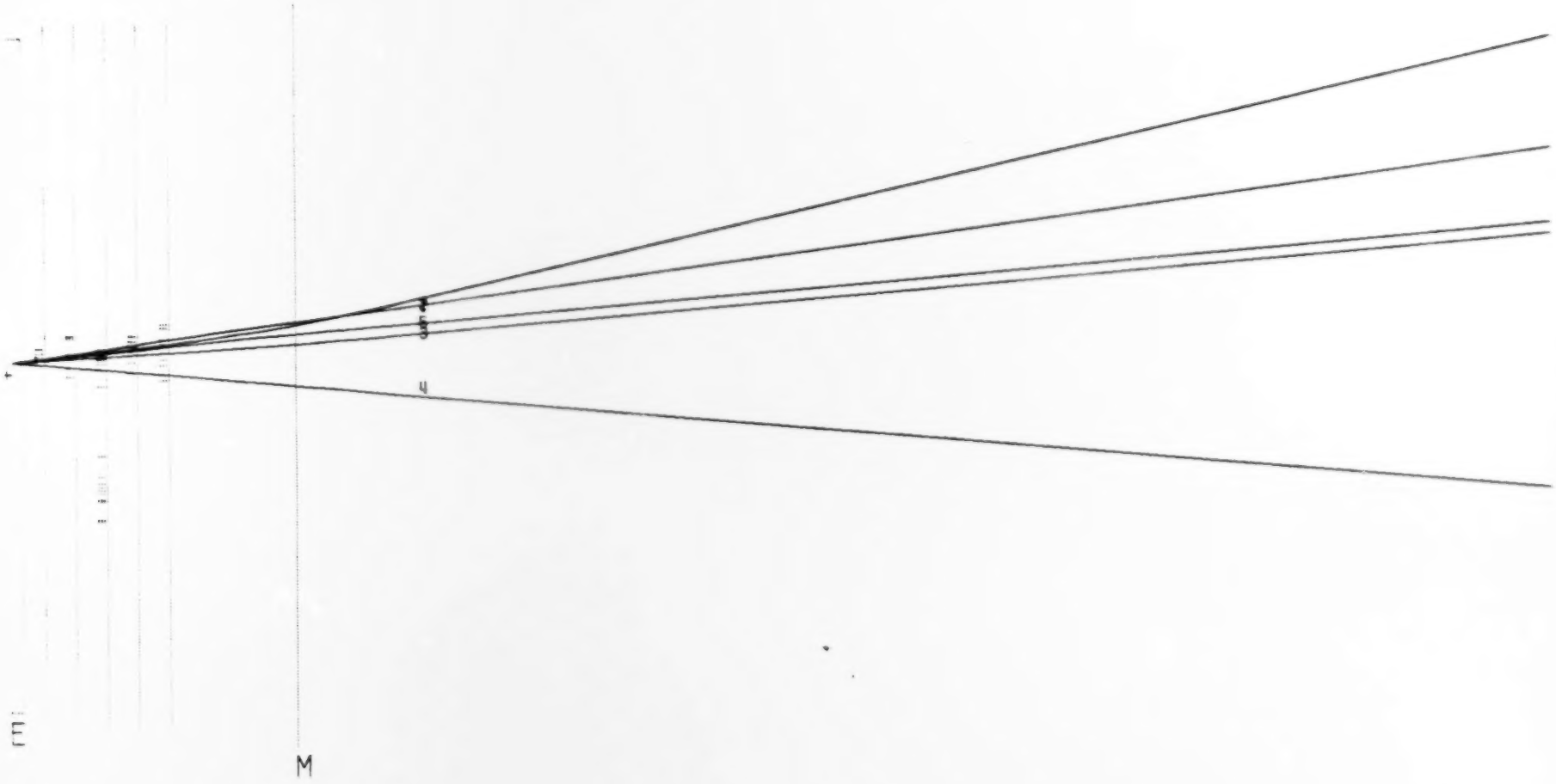

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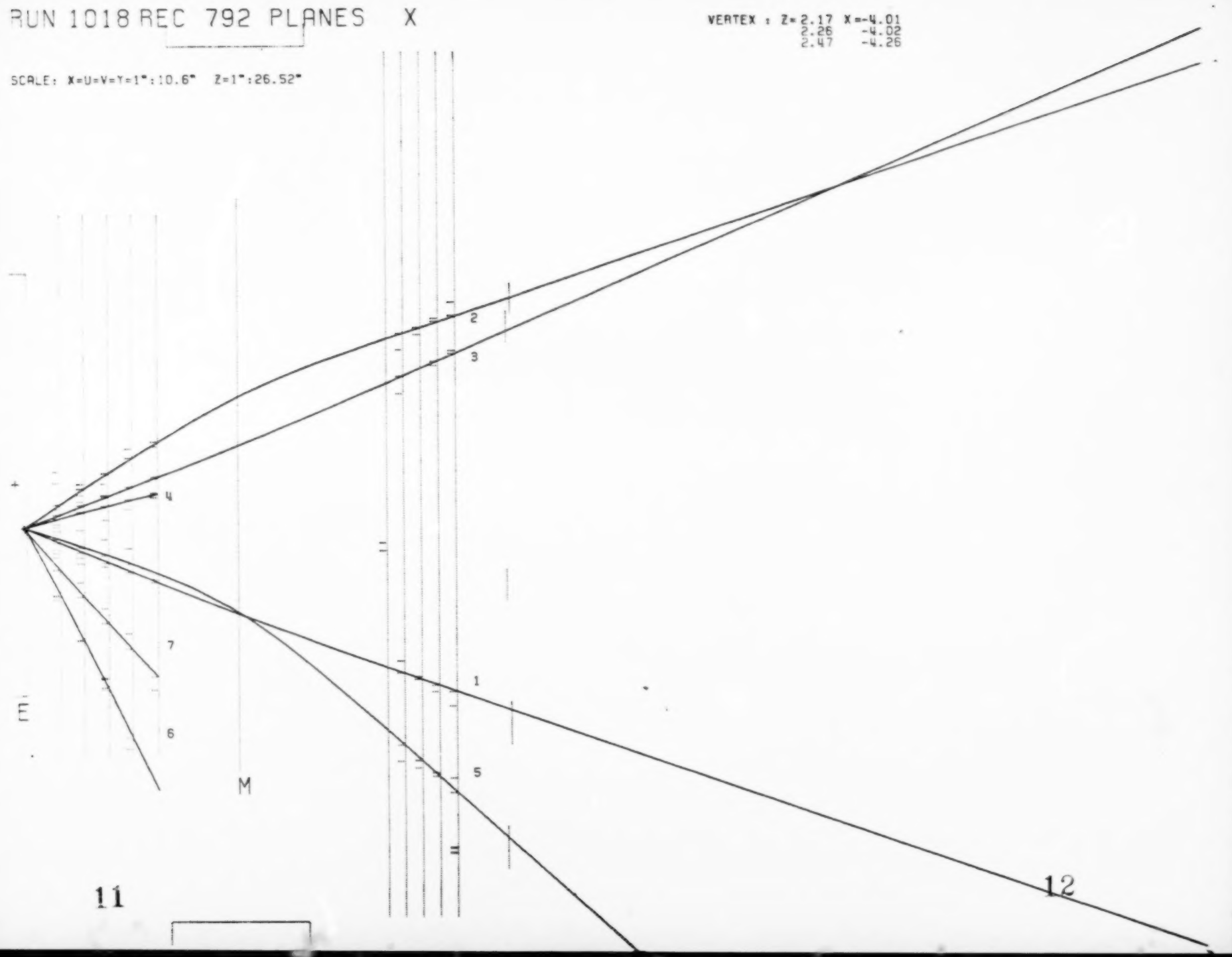
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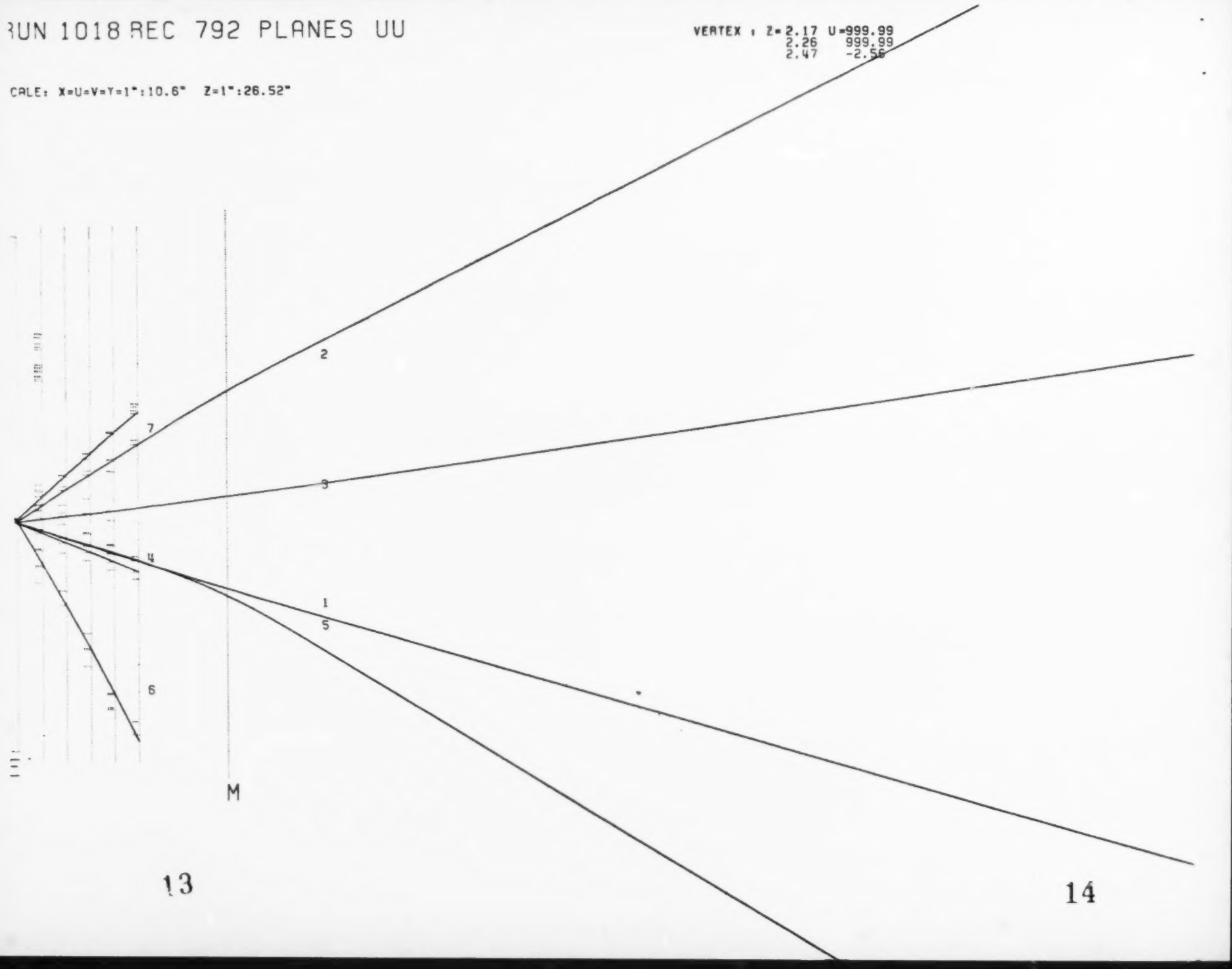
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5
6
M

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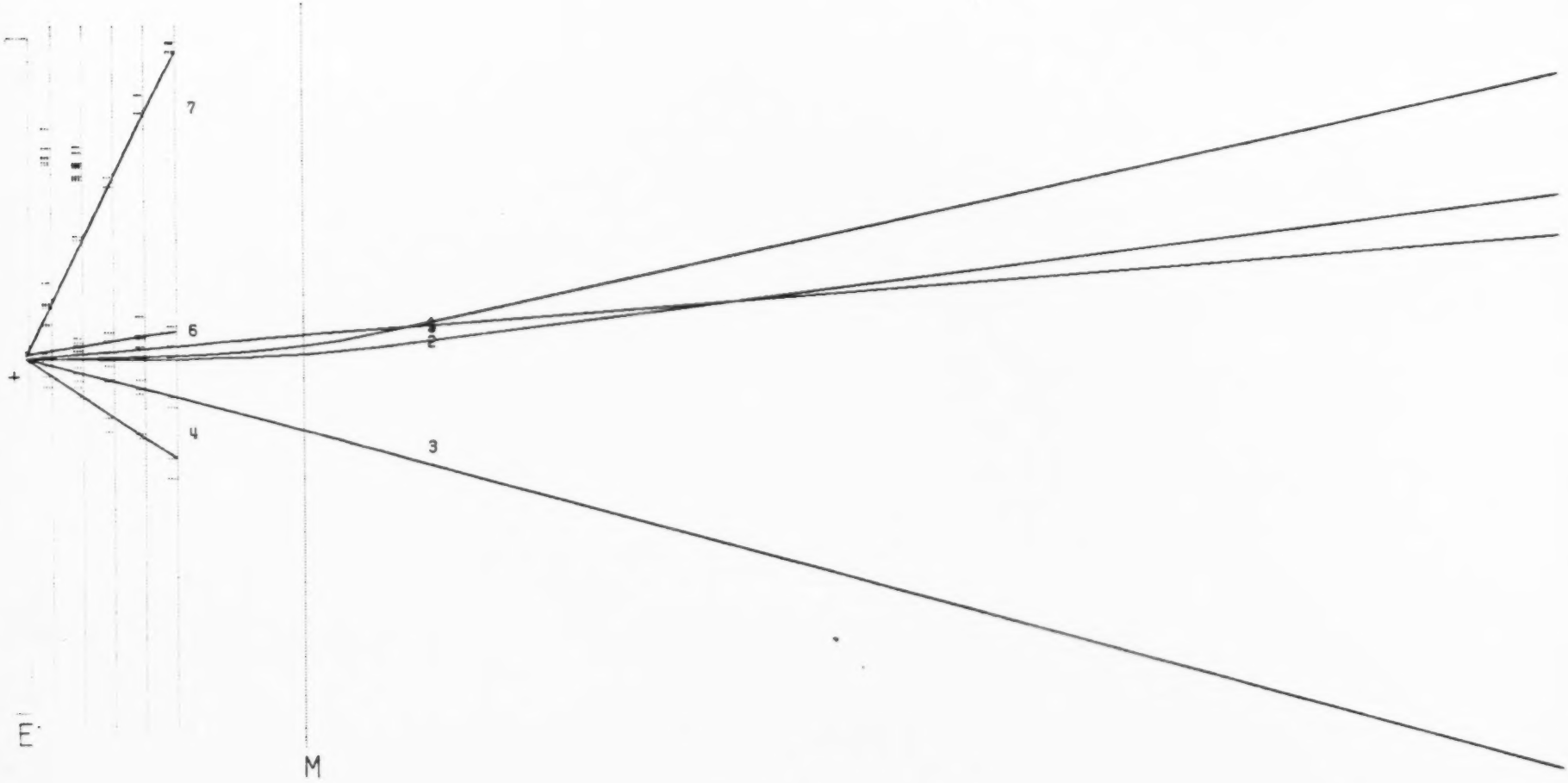

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We need to engage our students in physics and attack their misconception that physics is a dead subject, filled with boring facts and laws, all of which are complete and final words on their subjects. We know how exciting physics is, how rife with disagreements and seminal experiments. Our students at the elementary level see only the facade of the edifice of physics. While the facade appears complete, construction proceeds inside the building, and the entire structure is always being extended.

The restriction of introductory physics to what was learned in the 17th, 18th, and 19th centuries is unwise because it nourishes the feeling in our students that all of physics is determined and that nothing more remains to be learned. Predictability of ordinary events is important, but the idea that we should teach nothing but the most unrealistic simple ideas, ideas exactly expressed through solvable equations is unwise. We need to convey our excitement at physics to our students, our love of estimation, and the limitations of rigor. We want them to view the world differently after they've taken our courses.

We need to rethink our current choices of physics topics, and the sequence in which they are presented. Modern physics is important physics and its currency should not be considered a drawback to our pedagogic use of it. The existence of problems such as these can be considered opportunities for us to do something.

There are, in addition, other good reasons for considering a change in texts. Our 1950s curriculum, with its 1800s content, is not appropriate to the 1980s and 1990s. The availibility of microcomputers has changed in other ways our rationale for the sequence of topics (as well as the selection of topics). While the argument for restructuring course content because of microcomputer use is not as compelling intellectually as the arguments cited for inclusion of more modern physics, it is of more practical importance. There are more and more physicists who own and use micros. They will be more receptive to the introduction of such changes as nonlinearity, real air resistance, and other topics not usually found in our current introductory physics courses. This willingness to change should be channeled and used to assist in the rethinking of the introductory physics course in its entirety.

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